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Cross-Cultural Differences in Automotive HMI Design: A Comparative Study Between UK and Indian Users' Design Preferences

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Abstract

This paper presents a research study examining the importance of understanding automotive users' cultural values and their individual preferences for human machine interface (HMI) design features and functionalities. The goal of this research was to explore how a cultural model can be applied in the development of automotive HMI solutions and future design localization. To meet this goal, it was necessary to (a) identify the characteristics of the Hofstede cultural model, (b) identify the differences in cultural values using the model, and (c) identify regional differences in HMI design needs and preferences across drivers from India and the UK. The results highlighted differences in expectations for HMI systems between the groups, suggesting an influence of culture on the perception of vehicle user interface technology. This led to the conclusion that an understanding of cultural biases can influence design localization and support development strategies. In addition, two main categories of further research have arisen as a result of this project. The first category focuses on identifying methodologies to establish relationships between culture and regional drivers' HMI design preferences. The second category comprises new research questions on tools and processes to deal with cultural influences.

Keywords

automotive applications, automotive display information system, human machine interface, culture, user interfaces (UI), regional user, India, UK, cultural model, Kano model

Introduction

The majority of current automotive human machine interface (HMI) design largely focuses on the needs and preferences of drivers from Western markets and assumes a one-size-fits-all model. However the driving environment and driver attitudes in regions such as China and India are different from the West; as such Western models of automotive HMI design may not necessarily fit the needs of the region's drivers. Consideration of regional differences, particularly cultural aspects of HMI design, is important because all automotive manufacturers are looking beyond their traditional Western markets. With this in mind, if an automotive manufacturer wishes to expand into new regions, it is imperative that they understand the role of culture and its impact on driver perceptions of, attitudes towards, and preferences for user interfaces (UI) in a vehicle. This understanding is instrumental in facilitating technology uptake and improving design localization (Carey, 1998).

The field of human-computer interaction (HCI) has applied cultural models in many different ways to understand cultural influences in UI design. Cultural models are used to identify information that is cross-culturally appropriate, to avoid cross-cultural mistakes that can cause offence, to assess the degree of localization that will be necessary, and to evaluate the suitability of international interface (Hoft, 1996). For example, cultural models are used to compare websites of different countries (Callahan, 2005; Gould, Zalcaria, & Yusof, 2000) and to explain the acceptance and adoption of technologies in different countries (Barnett & Sung, 2005; De Angeli, Athavankar, Joshi, Coventry, & Johnson, 2004; Maitland & Bauer, 2001). Therefore, lessons learned about the relationship between HCI and cultural models can potentially benefit automotive HMI design.

Importance of Cultural Consideration in Automotive HMI Design

The importance of cross-cultural issues in vehicle HMI design has been acknowledged in several studies including, for example, the following: comparison between US and China in perceived hazard response to warning components and configuration (Lesch, Rau, Zhao, & Liu, 2009), comparison between Swedish and Chinese drivers in design of advanced driver assistance systems (Lindgren, Chen, Jordan, & Zhang, 2008), comparison of Australian and Chinese drivers in the use of in-vehicle information systems (Young, Rudin-Brown, Michael, & Amy, 2011), comparison between German and Chinese drivers in the use of a navigation system (Heimgartner, 2007; Heimgartner & Holzinger, 2005), and a comparison between UK and Indian drivers in the usability of HMI systems (Khan & Williams, 2014). These studies highlighted a range of cultural differences amongst participating groups, in terms of their UI preferences, navigation, driving, and task management styles that are relevant to HMI design. For example, it was found that Chinese drivers prefer greater speed in screen formation and information density and can cope with a greater number of tasks simultaneously compared to German or English drivers (Heimgartner, 2007; Heimgartner & Holzinger, 2005). Similar results have also been found by Khan and Williams (2014), where vehicle Bluetooth and navigation systems specifically designed to suit the visual perception and information decoding abilities of a specific culture (UK) were found to negatively impact the ability of people from another culture (India) to successfully interact with the system, as measured by task completion times and error rate. Young et al. (2011) found that Chinese drivers place less emphasis on safety and driver distraction, and on the appearance or aesthetic appeal of the HMI when compared to Australian users. In addition, Chinese drivers were less able to comprehend abbreviated text in the HMI system. At present however there is limited understanding of the nature of the observed differences, particularly their causes and impact relative to other factors. As such, there is a lack of recommended guidelines and tools available to deal with cultural issues in HMI design.

Understanding Cultural Dimensions

Many models operationalize culture and systematically divide it into measurable and comparable parts (Khan & Williams, 2014). Each of these models proposes a different way of understanding or qualifying the differences in culture. These cultural theories include Hofstede's pyramid model (Hofstede, 2005), Trompenaars' onion model (Trompenaars, 1993), and Hall's cultural factors (Hall, 1959), all of which consider culture to be comprised of at least an outer surface layer (the directly observable aspects of culture) and a deeper, hidden layer (the intrinsic aspects of culture, outside immediate awareness; Young et al. 2011). Amongst these, Hofstede's cultural model constitutes by far the most influential national cultural framework (Steenkam, 2001).

Hofstede conceptualized culture as “programming of the mind,” in the sense that certain reactions were more likely in certain cultures than in others, based on differences between basic values of the members of different cultures (Smith, Dunckley, French, Minocha, & Chang, 2004). Although nations may not be completely homogenous, they are the source of much of the collective “programming” of the people who live in them, and while the scores of nations on Hofstede’s cultural dimensions may vary, the relative position of one culture as compared to another will be fairly stable. Hofstede proposed five value dimensions, which have a significant impact on behaviour in all cultures, and ranked the surveyed countries on each of them; these are described in Table 1.These concepts were used to construct ideas about how technology acceptance may be affected by culture. For example, the researchers summarized that low individualism cultures will be less likely to communicate via computer mediated tools; this is because computer mediated communication, such as email, lacks the social cues of face to face contact and hence diminishes the group effect (Straub, Keil, & Brenner, 1997). Hofstede’s cultural model is also used as a tool to understand cultural differences in UI design. For example, the model has been used as a guide to the design of UI components (Marcus, 1998; 2003), such as metaphors, mental models, navigation, interaction, and appearance (Marcus, 2001; Marcus & Gould, 2000; 2015). The model has also been used to determine the extent of cultural influence in international websites (Smith et al. 2004) and to create guidelines for website localization (Sheridan, 2003). Thus, it can be argued that Hofstede’s cultural dimensions would be helpful to automotive designers in cross-cultural HMI design.

The interest in cultural models within the various design communities, especially HCI designers, has increased since Marcus and Gould (2000; 2015) derived UI guidelines directly from cultural dimensions. They suggest, for example, that information structure should directly correlate with the level of Power Distance; for example, high Power Distance users require highly structured information presentation while low Power Distance users require less structured information presentation.

Objectives of the Study

The aim of this study was to explore the differences in attitudes and preferences towards automotive HMI design and feature requirements between users from two cultural groups: India and the UK. In order to achieve this goal, we wanted to (a) identify the characteristics of the Hofstede cultural model, (b) identify the differences in cultural values using the Hofstede cultural model between drivers of the two cultural groups, and (c) identify regional differences in HMI design needs and preferences across drivers from India and the UK. Based on these, the following hypotheses were assumed:

> H_1: There are significant differences in cultural values and orientation between two cultural groups who use automotive HMI.
>
> H_2: There are significant differences in preferences for user interface attributes and features between the aforementioned cultural groups.

Based on previous studies by Hofstede (1980; 1986), it was expected that significant differences between Indian and UK drivers would be found in terms of their cultural values that could significantly influence their HMI feature preferences. As such, this paper will contribute to the understanding of cultural adaptation and customization of visual features within the automotive HMI system in emerging countries.

Methods

This study considered national cultures as a context and source of differences in how people relate to, work with, and come to understand and communicate their preferences in UI systems. As such, Hofstede’s Value Survey Module 2008 (VSM08; Hofstede, Hofstede, Minkov & Vinken, 2008) was selected as the tool with which to measure cultural differences. Unfortunately, no such survey module exists with other models to make comparisons among cultural groups. Therefore the current study focused on the cultural dimensions developed by Hofstede (2001; 2005).

Definition of User Requirements

Marcus and Gould's (2000; 2015) guidelines serve as a framework for determining how cultural differences can influence components of UI design and are therefore used within the current study as a means to test the differences in regional driver's preferences in automotive HMI design requirements. Table 2 lists the UI requirements for the HMI used in the study. The requirement list was adapted from Marcus and Gould's guidelines and mapped to the Hofstede cultural dimensions, based on their approach.

Table 1. Five Dimensions of Hofstede's Cultural Model

Cultural dimensions	Definition	Characteristics	Example countries
Power Distance Index (PDI)	Extent to which the weaker members of a society accept inequality in power	*High Power Distance*: Centralized decision making, management and superiors are highly respected and have the last say in decisions. *Low Power Distance*: Everyone expects to share in decision making; management hierarchies are flatter and more open to questioning.	Germany and Scandinavian countries score low on this dimension.
Individualism vs. Collectivism Index (IDV)	Relationship between individuals and groups	*High Individualism*: Social ties are loose; individuals expected to look after themselves. *High Collectivism*: Individuals are strongly incorporated into groups of family and school; government policies often favor the group over individual rights.	Individualistic countries are Australia, Canada, US, UK, and Holland. Latin America countries are extremely collectivistic countries.
Masculinity vs. Femininity Index (MAS)	Distribution of emotional roles between genders	*High Masculinity*: Favors assertiveness with an emphasis on competition. *High Femininity*: Focuses on quality of life with an importance placed on the well-being of relationships.	Japan scores high on Masculinity; countries that score high on Femininity are Sweden and Norway.
Uncertainty Avoidance Index (UAI)	Extent to which a society feels threatened with unknown situations, ambiguity, and uncertainty	*High Uncertainty Avoidance*: Strictly defined rules of behavior and formality; things that are different or unexplained can be viewed as dangerous. *Low Uncertainty Avoidance*: Willingness to take risks, more experimentation and/or innovative behavior.	Countries that score high on this dimension are Latin countries; countries that score low are Denmark, Sweden, and Singapore.
Long- vs. Short-Term Orientation Index (LTO)	Extent to which members of a cultural group are willing to accept delayed gratification of material, social, and emotional needs	*Long-Term Orientation*: Promotes virtue and persistence, focus towards future rewards. *Short-Term Orientation*: Emphasis is placed on the past and present, fosters a respect for tradition.	Philippines, Nigeria, and Pakistan display low in Long-Term Orientation index

The user need analysis was carried out using the Kano model (Kano, Seraku, Takahashi, & Tsuji, 1984). This model is an effective tool for understanding customer preferences due to its convenience in classifying customer needs based on survey data. The Kano model has been applied to a wide variety of products and services including strategic thinking, business planning, and product development (Watson, 2003). According to Kano, invisible ideas about user defined quality can be made visible with a clear requirements classification (Berger et al., 1993). The model captures the nonlinear relationship between product, performance, and customer satisfaction (Xu, Jiao, Yang, & Helender, 2009) by classifying product attributes in to the following four categories:

- *Must-be* requirements (*M*): Some requirements whose presence adds no value but absence impacts customer satisfaction very negatively, can be classified as *Must-be* (Rejeb, Guimaraes, & Boly, 2008). As these requirements represent a fundamental customer need, their fulfilment will not increase satisfaction. Fulfilling the Must-be requirements will only lead to a state of "not dissatisfied" (Matzler & Hinterhuber, 1998).
- *One-dimensional* requirements (*O*): For some requirements, customer satisfaction can be proportional to the level of product functionality. Kano designated such customer requirements as *One-dimensional* (Rejeb et al. 2008). One-dimensional requirements are usually explicitly demanded by the customer (Matzler & Hinterhuber, 1998); therefore, if these types of requirements are fulfilled, they can become a strong source of customer satisfaction.
- *Attractive* requirements (*A*): Requirements whose presence adds values to the products or services, but their absence has no negative impact can be classified as *Attractive* (Rejeb et al., 2008). As such, even if they are not met, they will not cause any dissatisfaction. Attractive requirements are neither explicitly expressed nor expected by the customer; however, fulfilling these requirements leads to greater-than-proportional levels of satisfaction (Matzler & Hinterhuber, 1998).
- *Indifferent* requirements (*I*)*:* In certain cases the presence or absence of this requirement will make no difference to customer satisfaction, hence, this requirement is of no importance to the customer and can be classified as *Indifferent* (Rejeb et al., 2008). This classification indicates that the customer is not interested in the level of performance of the requirement (Xu et al., 2009).

The features within a user requirement can be classified using a questionnaire based on a functional and dysfunctional approach (Berger et al., 1993). For each of these requirements, a pair of questions is formulated to which the user can respond in one of five different ways. The first of the pair of questions asks the user how he or she would feel if a feature within a requirement is available (the functional form of the question); while the second part asks how he or she would feel if that feature is not available (the dysfunctional form of the question). For each pair of questions, the following options are given: (a) I like it, (b) it must be that way, (c) I am neutral, (d) I can live with it, or (e) I dislike it (Kano et al., 1984). The need classification is then obtained by comparing the responses to the functional and dysfunctional questions to an evaluation table, which identifies the classification of the requirement (Matzler & Hinterhuber, 1998; Rejeb et al, 2008).

The analysis and interpretation of the Kano results was carried out in the following steps:

Step 1: According to Kurt and Hans (1998) and Kurt, Hans, Franz, and Elmar (1996), the simplest method is evaluation and interpretation according to the frequency of answers. Therefore, the frequencies (as percentages) of classification in each category were calculated for each UI feature.

Step 2: Certain requirements may be classified in more than one category. The rule $M > O > A > I$, proposed by Kurt and Hans (1998), is therefore adapted for the evaluation of responses, allowing the highest-priority category for that requirement to be identified.

Step 3: Customer satisfaction (CS) coefficients are calculated from the Kano category frequencies using the formulae, shown in (1) and (2) below, where *A*, *O*, *M*, and *I* signify the number of responses in the Attractive, One-dimensional, Must-be, and Indifferent categories respectively, as per the Kano model definition. CS indicates the extent to which satisfaction increases if a product requirement is met or the extent to which satisfaction decreases if a product requirement is not met (Berger et al., 1993). Thus, the CS coefficients are indicative of how strongly product features correlate with customer satisfaction and dissatisfaction in the case of fulfilled or non-fulfilled requirements (Matzler & Hinterhuber, 1998). CS is widely used in in areas such as digital products (Zhu, Lin, Tsai, & Wu, 2010), customer services (Sihombing, Chidabaram, & Passiah, 2012), patient care (Hejaili, Assad, Shaheen, Moussa, & Karkar, 2009), and automotive quality (Rashid, Tamaki, Ullah, & Kubo, 2010).

$$\text{CS} - \text{E (Enhanced)} = \frac{A + O}{A + O + M + I}\, X\, 1 \qquad (1)$$

$$\text{CS} - \text{R (Reduced)} = \frac{O + M}{A + O + M + I}\, X\, (-1) \qquad (2)$$

Table 2. Adapted Requirement Definition of the Study

Cultural dimensions	Classification	UI attributes	Feature Requirements	Codification
Power Distance Index (PDI)	High	Information style	Provide highly structured information	f1-1
		Access to information	Focus on authority and security of the system	f2-1
Uncertainty Avoidance Index (UAI)	High	Menu structure	Ensure minimum and single type of menu option features	f3-1
	Low		System can have many menu options with several types for features	f3-2
	High	Text options	Provide descriptive text for system features	f4-1
	Low		Provide abbreviated text for system features	f4-2
			Each text should be supplemented by images	f4-3
Masculinity vs. Femininity Index (MAS)	Masculine	Number of steps	Ensure limited tasks options are available for each feature	f5-1
		User help	Provide a help button for each feature	f6-1
			Provide informative feature for user exploration	f6-2
		Gender distinction	Ensure explicit distinction between gender and age for each feature content, help, and text option	f7-1
	Feminine	Aesthetic appeal	Aesthetic appeal and color options	f8-1
Individualism vs. Collectivism Index (IDV)	Individualist	Content style	Provide an option for personalization and feedback	f9-1
			Provide images of materialism; emphasize new features of the system	f9-2
	Collectivist		Provide cross-national symbol for features	f9-3
Long- vs. Short-Term Orientation Index (LTO)	Short-term	Navigation style	Overall navigation style should be simple	f10-1
	Long-term		Navigation style can be varied and complex	f10-2

Study Design

In this study, the cultural group and automotive HMI display features under user test form the independent variables, while the Hofstede VSM08 and Kano questionnaire responses form the dependent variables. Demographic and user experiences with technology are treated as extraneous variables. A mixed experiment design was employed with *cultural group* as a between-subjects factor and *HMI tasks* a within-subjects factor, such that all subjects from each group experienced the full range of HMI features. In accordance with the study objectives, emphasis was placed on the cultural and attribute preference data, and task performance measures were excluded.

Participants

The focus of this study is on Hofstede's cultural dimensions and evaluating user cultural values within these dimensions. Therefore to improve reliability while enhancing generalizability, a set of countries offering similarities across a number of aspects while being as far apart as possible on the Hofstede theoretical dimension of concern should be chosen (Alden, Hoyer, & Crowley, 1993; Sivakumar & Nakata, 2001). Thus, two countries were selected: India and the UK. These countries have similarities within some cultural dimensions; however, most dimensions show profile differences (Hofstede, 2014). Participants were required to be either Indian or UK citizens aged 18 years or over, live in the Pune or Warwickshire regions, and hold a valid driver's license. Additional criteria of minimum residency in the local region (12 months), minimum experience of touch screen systems, and minimum driving experience (12 months) were applied.

Use of students is a widespread practice in cross-national research (Durvasula, Lysonski, & Andrews, 1996; Steenkamp & Baumgartner, 1992; 1995); thus, 60 engineering students taking graduate and post-graduate level courses in the Pune Engineering College and the University of Warwick were recruited for the study (30 in India and 30 in the UK). A faculty member from each institution served as the contact person. For the study in India, copies of the survey questionnaires along with testing instruments and instructions were sent to the faculty member who then directed the implementation of the study. The same protocol was used at the University of Warwick.

Table 3 shows the demographic data of the two cultural groups. The groups were compared in each category using a contingency table approach with Fisher's exact test; this showed significant differences between the UK and Indian samples in all categories except gender and age. These differences however are not considered to be detrimental to the findings of the research. Indian participants displayed a higher level of geographical mobility, reflecting trends towards increases in urban populations in the country (Abbas & Varma, 2014). The differences in driving experience may also reflect broader trends of vehicle ownership across the two countries (Kalmbach, Bernhart, Kleimann, & Hoffmann, 2011). While UK users tended to have a greater degree of prior touch screen experience, all of the participants in the study received training on the touch screen tasks and achieved the required level of competence prior to taking part in the study.

Table 3. Demographic Amongst the Two Cultural Groups

Characteristics		**Cultural background**		**P-value**
		UK (%)	*India (%)*	
Gender	Male	83.33	86.67	1.00
	Female	16.67	13.33	
Age	Between 20 – 25 years	46.67	53.33	0.864
	Between 25 – 30 years	43.33	40.00	
	Between 30 – 35 years	10.00	6.67	
Education	Bachelors	36.67	0	0.00
	Masters	63.33	100	
Living in current place	1-2 years	14.29	13.33	0.00
	2-3 years	7.14	43.33	
	3-4 years	0.00	16.67	
	>4 years	78.57	26.67	
Driving experience	1-2 years	7.14	36.67	0.00
	2-3 years	0.00	33.33	
	3-4 years	7.14	10	
	4-5 years	0.00	6.67	
	>5 years	85.72	13.33	
Experience with touch screen systems	1-2 years	7.15	36	0.00
	2-3 years	0.00	30.67	
	3-4 years	14.28	16.66	
	4-5 years	21.42	10	
	>5 years	57.15	6.67	

Data Collection and Experimental Procedure

Data was collected over three weeks in April and June 2014 at six automotive HMI evaluation laboratory sessions conducted at Pune Engineering College and University of Warwick. Each laboratory session involved 10 participants and lasted approximately 60 minutes. The experimental procedures and survey questionnaires used for both cultural groups were identical and written in British English language.

The context of use is critical to how users perceive technology and as such should be replicated within evaluation scenarios (Hassenzahl, 2004). Two samples of automotive touch screen UIs, based on HMI from two production vehicles, were therefore chosen to be assessed in the laboratory. The selected samples were adapted from existing systems, ensuring that the intended context of use was preserved during the evaluation. Two criteria were used to select the touch screen HMI samples: firstly, the touch screen information and layout style had to be recognized by both cultural groups. Secondly, the vehicle type and tablet used had to be available in both the UK and Indian markets. Figure 1 shows the samples of display screen layout associated with HMI feature requirements. The samples differed in their design characteristics in order to provide examples of each of the 17 functional requirements defined in Table 2. The interfaces were de-branded and presented on a 7-inch Android tablet in order to minimize product bias; this was integrated into a static development vehicle interior cockpit for the evaluation as shown in Figure 2. The cockpit was also equipped with tactile center console and steering wheel control switches; along with the touch screen, these allowed users to operate navigation, Bluetooth hands-free telephony and multimedia functions of the vehicle's HMI.

SAMPLE A: Structured Information (*f1-1*)
SAMPLE A: User exploration (*f6-1*)
SAMPLE B: Text with Image & Icon (*f4-3*)
SAMPLE B: Descriptive text type (*f4-1*)

Figure 1. Screen layout samples associated to HMI feature requirements.

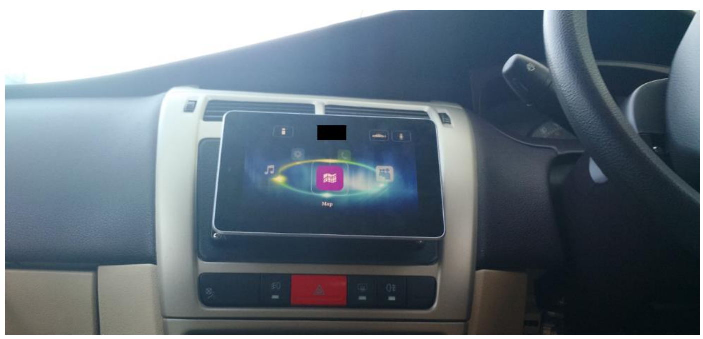

Figure 2. Laboratory environment of the study.

Participants began by signing a consent form and filling out pre-experiment questionnaires in order to collect their demographic information and cultural values. Respondents indicated their answers using a 5-point Likert scale with five dimensions of culture represented on the basis of four questions per dimension as specified by Hofstede (VSM08). Participants received training to familiarize them with the basic operations of the touch screen system and information flow of the developed HMI. Once complete, the participants in the laboratory were given a series of UI tasks to complete using the touch screen. Using scenario-based analysis, a number of information handling and analysis tasks that the target user would be likely to perform while driving were identified. These included display menu settings, selecting a music track, making a telephone call, and selecting a destination using navigation.

The following is an example of the sequence of a task: The experimenter reads the task aloud before execution, for example: "Please navigate to the telephone directory in the touch screen. Please find Christopher's contact information by using the scroll down contact list in the telephone directory and make a call to Mark on +44(0) XXXXX-XXX027 (UK laboratory) or +91(0) XXXX-XXXX006 (Indian laboratory)." A task was counted as successfully completed if the HMI came to a logical stand point, for example, if an outgoing call screen was displayed. A task was counted as unsuccessful if there is no logical screen displayed or the participant announced he/she was unable to complete the task, or did not wish to continue with the task. Participants were then asked to rate their preferences based on their touch screen use experiences using the Kano model-type questionnaire. For each of the 17 functional requirements, participants were shown an image from the HMI (from either sample A or B) reflecting that requirement, then asked to answer the functional and dysfunctional forms of the Kano questionnaire; for example: "How would you feel if the HMI provided menu selection options in the phone display screen?" (functional form) and "How would you feel if the HMI did not provide menu selection options in the phone display screen?" (dysfunctional form).

Statistical Processing

Mean cultural value scores were calculated using the formula defined in Hofstede VSM08 and comparisons between the two groups were made for each cultural dimension using 2-tailed student *t*-tests. The internal consistency of the survey data was evaluated using Cronbach's Alpha. Mean CS-E and CS-R scores were also calculated for each attribute and compared across cultural groups using *t*-tests (2-tailed). Significance is determined at $\alpha = 0.05$ for all tests.

Results

Results from the Hofstede cultural value survey are shown in Table 4. The results demonstrate significant differences in Power Distance, Individualism and Long-Term Orientation indexes between the two cultural groups. The participating Indian sample tended to be more Long-Term Oriented and possess high Power Distance, while exhibiting lower scores for Individualism and Uncertainty Avoidance. In comparison, the participating UK sample is more Individualist, Short-Term Oriented and scores more highly on Uncertainty Avoidance. There was no statistical significance observed in the MAS index. Data reliability shows Cronbach's Alpha exceeds 0.70 in all cases, indicating good reliability (Nunnally, 1978). The results clearly provide evidence to accept the hypothesis (H_1) that significant differences exist in cultural values and orientation between the two tested cultural groups who use automotive HMI.

Table 4. Cultural Values Amongst the Participating Groups

Cultural dimension	Cultural values				Cronbach Alpha (α)	
	UK	India	t(df)	P-value	UK	India
PDI	50.83	102.67	-3.24(31)	0.002*	0.955	0.714
IDV	149.27	52.67	6.74(39)	0.000*	0.792	0.703
MAS	73.78	82.83	-0.57(32)	0.569	0.895	0.704
UAI	7.78	0.50	0.33(39)	0.737	0.996	0.906
LTO	30.83	91.33	-2.96(32)	0.005*	0.707	0.927

* = $p < 0.05$

The customer satisfaction coefficients derived from the Kano questionnaire are shown in Table 5. Comparing the mean CS values across cultural groups using the *t*-test for unequal variances confirms that significant differences exist between UK and Indian users for both Extent of Satisfaction (CS-E: $t(25.3) = 2.07$, $p = 0.049$) and Extent of Dissatisfaction (CS-R: $t(27.1) = -2.42$, $p = 0.023$). This confirms the hypothesis (H_2) that there are significant differences in the preferences for UI attributes and features between the two cultural groups of automotive HMI users.

Based on the method proposed by Berger et al. (1993) and referenced by Xu et al. (2009), a two dimensional Kano diagram is established by plotting CS-E against CS-R for both cultural groups, as shown in Figure 3. The diagram is divided into four quadrants representing the four Kano categories, and accordingly the UI features are classified by their CS scores.

For UK users, none of the features are identified as Must-be requirements. This indicates that the attributes tested during the study were not viewed as essential within the user base. Indian users identified "Many menu options" (f3-2) and "Informative feature for user exploration" (f6-2) as Must-be requirements, indicating that Indian users held stronger opinions on functionality requirements for vehicle HMI. Notably, "Help button for each feature" (f6-1) and "Informative feature for user exploration" (f6-2) attract similar scores for the Indian group, indicating potential dissatisfaction if not adequately delivered. Both of these requirements relate to access to user help functions within the system, highlighting the importance of support functionality to Indian users.

"Personalization option and feedback" (f9-1) and "Text with image option" (f4-3) were identified as Attractive requirements for UK users, while "Complex navigation style" (f10-2) and "Aesthetic appeal and color option" (f8-1) were Attractive requirements for Indian users. The result for "Provide an option for personalization and feedback" (f9-1) is interesting as UK users scored significantly higher on the Individualism index and might therefore be expected to place a higher degree of importance on personalization features and thus identify this as a One-dimensional requirement. "Highly structured information" (f1-1) and "Limited task options" (f5-1) each attracted similar scores from the UK and Indian groups, identifying a common need for these features across cultures. Both are One-dimensional attributes, signifying a proportional relationship between delivery and satisfaction, and both relate to the clarity of information presentation, which will influence the usability of the system. The implication therefore is that usability is a universal requirement for all user groups that must be established in order to deliver a satisfying product.

While no significant difference was observed between UK and Indian users for Uncertainty Avoidance, Choi, Lee, Kim, and Jeon (2005) identified that high Uncertainty Avoidance users feel threatened by ambiguous situations and tend to prefer an efficient layout or space usage where a large amount of information can be displayed, supported by clear menu labelling with images. When implemented within a vehicle HMI, these parameters can help drivers to complete interaction tasks efficiently. Choi et al. (2005) also identified that users from low Uncertainty Avoidance cultures can cope well with ambiguity and can be characterized as risk-takers, with a positive attitude towards new experiences (Hofstede, 2007). This is reflected in the CS-R rating of "Informative feature for user exploration" (f6-2) for Indian users, suggesting that restricting users' ability to explore the system will cause dissatisfaction.

"Simple navigation style" (f10-1) is One-dimensional for both UK and Indian users, again indicating a proportional relationship between functionality and satisfaction and suggesting a link to usability. However, "Navigation style can be complex" (f10-2) is also an Attractive feature for the Indian user group. These two requirements are seemingly contradictory (simple vs. complex), yet there is potential for increased satisfaction if the *complex* style can be implemented without disrupting delivery of the *simple* style, for example, with a configurable display setting; this should be carefully considered in the design of a new HMI. As "Images of materialism and emphasis on new" (f9-2) and "Complex navigation style" (f10-2) also have a positive influence on satisfaction for Indian participants (CS-E scores 0.65 and 0.70 respectively), with f9-2 also influencing dissatisfaction, it is suggested that a "high-tech" appearance to touch screen HMI is desirable for Indian users. The requirement f9-2 also exhibits the largest difference between the two user groups serving as a clear illustration of difference between the sets of participants.

Table 5. Comparing Customer Satisfaction Coefficient (CS) Amongst Participating Groups

	Extent of Satisfaction (CS-E)		**Extent of Dissatisfaction**	
	UK	India	UK	India
f1-1	+0.64	+0.54	-0.57	-0.50
f2-1	+0.00	+0.32	-0.00	-0.41
f3-1	+0.43	+0.35	-0.43	-0.35
f3-2	+0.25	+0.40	-0.25	-0.60
f4-1	+0.00	+0.26	-0.00	-0.37
f4-2	+0.33	+0.29	-0.00	-0.33
f4-3	+0.62	+0.48	-0.46	-0.52
f5-1	+0.79	+0.64	-0.64	-0.75
f6-1	+0.36	+0.50	-0.36	-0.61
f6-2	+0.44	+0.48	-0.22	-0.55
f7-1	+0.13	+0.48	-0.13	-0.60
f8-1	+0.20	+0.52	-0.10	-0.19
f9-1	+0.58	+0.46	-0.25	-0.57
f9-2	+0.00	+0.65	-0.00	-0.50
f9-3	+0.40	+0.56	-0.20	-0.52
f10-1	+0.69	+0.81	-1.00	-0.54
f10-2	+0.00	+0.70	-0.00	-0.00
Mean (SD)	0.34 (0.26)	0.50 (0.15)	0.27 (0.28)	0.47 (0.18)
P	0.049*		0.023*	

* = p < 0.05

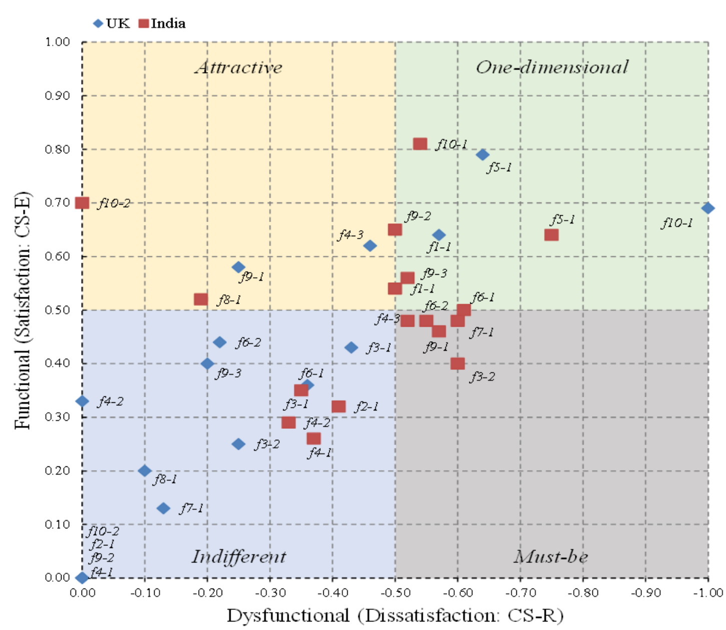

Figure 3. Kano customer coefficient (CS) diagram.

Discussions

Using the Kano-style user evaluation in India and the UK, this study identified automotive HMI design features that regional drivers from these two cultures value. The study also identified differences in HMI feature preferences between the two cultural groups. The findings suggest that regional differences can influence the acceptance of automotive HMI attributes and as such culturally-generated HCI UI guidelines may be applied as a basis for future automotive HMI design. Selection of features appears to be culturally biased: for example, Indian participants tended to be Collectivist and possess high Power Distance and were satisfied when features such as user help, gender distinction, and cross-national symbol are implemented in the HMI system. This agrees with Marcus and Gould's (2000; 2015) assertion that content and structure can be designed in such a way that facilitates distinctive layout, style, and user friendliness between male and female users. Therefore automotive HMI designers should pay attention to these types of needs when designing for a region where these cultural values are prevalent. It is clear that complexity within the navigation styles provides high satisfaction within this study for a Long-Term Oriented cultural group such as India, but the absence of complexity does not induce dissatisfaction. To deal with such user needs, good practice would be to carefully analyze the interaction scenarios, which require high driver mental workload, and to determine the characteristics of distraction these may cause (Pickering, Burnham, & Richardson, 2007), and then design to limit distraction while driving.

The study found that both UK and Indian groups regard the *limited tasks option* HMI feature as a One-dimensional requirement. Both groups also score highly on the Hofstede MAS index; this again agrees with Marcus and Gould's (2000; 2015) guidelines, suggesting that in a masculine culture, there will be a preference for simplified interfaces. To eliminate customer dissatisfaction in such scenarios, the designer can consider the development of shortcut keys for driver interaction. Particular attention should be given to the speed of response of the system. The results also show that Indian participants found emphasis on a new idea or material and aesthetic appeal and color option very attractive. Therefore the designer can consider an option to provide customized options for color, font, and images to attract user attention in Long-Term Oriented regions. In addition, options to provide content personalization and legible text are potential delight features for UK participants if successfully implemented. The designer can consider providing a design image with textual information to gain user attention in an individualist culture that may help to improve the efficiency of user interaction tasks during driving.

This study could not verify all the expected results as per Hofstede's cultural theories. For example, the MAS and Uncertainty Avoidance indices presented a pattern contrary to the expected direction. There may be several explanations for these inconsistencies. Firstly, previous cross-cultural studies (e.g., Fernandez, Carlson, Stepina, & Nicolson, 1997; Heuer, Jeffrey, & Winfred, 1999; Hoppe, 1990; Merritt, 2000) demonstrated that Hofstede's VSM produced inconsistent results, with sample size and selection influencing outcomes. Furthermore, studies that measured Hofstede's national dimension using different scales also reported variations in country rankings in relation to his original data (Fernandez et al., 1997). Secondly, although on the surface a culture may appear similar based on their national identity, diversity exists in cultural values and attitudes among members of any given national culture. Therefore, the Indian and UK participants' cultural diversity may have played a role in the differences between actual and expected results. In fact, previous research suggests that India has no clear positions on three of Hofstede's dimensions due to the highly complex and pluralistic nature of the culture, containing seemingly inconsistent and contradictory orientations (Arora, 2011; Shrivastava & Shrivastava, 2012). For example, Indians are observed to be polite, non-assertive, emotional, tolerant, and feminine in some of their orientations (Arora, 2011), but these characteristics, "are juxtaposed by a strong need for material influence, power and control, status in society, and other signs of masculinity" (from *Culture and Personality* by Nandy & Kakar as quoted in Sinha, 2004, p. 93). Furthermore, any generalization about Indian culture has to acknowledge the differences due to the country's size and regional culture. Therefore, Indian participants may display more flexibility and logical understanding on the surface and how they portray their public self, but privately they may feel and think very differently, which is an ardently maintained Indian trait (Arora, 2011). This separation of surface and inner core spheres may have generated conflicting outcomes for the study. Hence, while this study confirmed that cultural models can help automotive designers make a culturally generated interface design, this may not be always the only route to understand the needs of users; culture may not be the only factor in the differences in vehicle UI preferences observed across regions and countries.

The Kano model is applied in the context of product quality to provide useful information about the types of requirements that must be fulfilled to enhance customer satisfaction. In this study, the Kano model was applied to identify regional users' preferences for HMI feature design. Although numerous studies have employed the Kano method, it is not without weaknesses. This study experienced a practical problem with the model's definition of Attractive requirements during the Kano survey questionnaire development as well as analysis of survey responses. For example, the original model defines Attractive if the requirement elicits customer satisfaction when fulfilled, but does not cause dissatisfaction when not fulfilled (Berger et al. 1993; Matzler & Hinterhuber, 1998; Mikulic, & Prebezac, 2011). However, further studies revealed that some researchers interpreted the definition as "are present or have sufficient performance," but do not cause dissatisfaction when "not present or their performance is insufficient" (Tontini & Silveira, 2007, p. 486). Interpreting the later definition implies that the Kano model provides similar classification regardless of whether features are fulfilled or not-fulfilled in terms of presence or defined performance. These contradictory definitions caused significant confusion during participants' responses and to the analyses of some response categories. Previous research also reports this issue (Mikulic & Prebezac, 2011). To alleviate the confusion, this research adopted the original Kano model definition defined by Berger et al. (1993). Further study to define an easier and more interpretable definition may provide many more differences on regional automotive users' HMI design preferences.

Limitation of the Study

Although this study makes a good contribution to furthering cross-cultural research in automotive HMI, it is not without limitations. The first limitation of this study is due to selection of the samples and their characteristics. Participants were selected from academic institutions in India and the UK; therefore, it is feasible that one cause of inconsistency may be due to the relative youthfulness and lack of professional experience of the university students used for the study. Therefore, using a different or wider participating demographic as opposed to only students, as this study used, would make the findings more generalizable for automotive designers. For example, different groups that include participants with HCI design knowledge, more female participants, and different ages could provide further insight of cultural influence in future HMI design.

Secondly, while maintaining context, the use of production-based HMI samples reduced experimental control over individual factors by not presenting the participant with opposing levels for each requirement (e.g., high and low levels of structured information). This could be addressed in future studies by creating custom HMI examples specifically for the study.

The study was focused on the determination of differences in cultural values and HMI attribute preferences between the two user groups, and relative task performance was not evaluated. Although users received training prior to conducting the tasks, individual differences in performance may have influenced users' preferences for HMI attributes.

Finally, issues exist with the cross-cultural comparability of measurement in survey responses. It is accepted that survey responses may be culturally influenced (Hejaili et al., 2009) and as such individuals may understand the same question in different ways (Brady, 1985); therefore, it is inevitable that participants' comprehension of survey questions will influence their responses. Furthermore, although driving and prior technology usage experience were factored into the study, conducting the study in a static condition excludes the influence of driving-related factors such as regional traffic and climate. As such, further study regarding the process of continuous HMI performance and localization measurement should be carried out to identify these challenges.

Recommendations for Future Work

This study utilized knowledge and methodologies from the HCI field to deal with cultural differences in the feature design and assessed their usability in automotive HMI. This study provides rich results that have the potential to be exploited further.

- The usage of appropriate industrial tools for automotive designers and usability engineers to obtain information regarding cultural differences and the relationship with users' design preferences towards future HMI solutions could be further explored. In this regard, a qualitative methodology such as in-depth interviews or polychronic time orientation across cultures (Hall, 1983) or socio economic classification (Blishen, 1958; Duncan, 1961; Nam, 1963) could complement the study results. Furthermore, many standard cross-cultural measurement tools used in the HCI field such as cultural finger print, utility theory, and so on, have yet to be validated within the automotive HMI domain. Validating any of these tools in cross-cultural settings would make a significant contribution to the field of future automotive HMI design.
- This research could be expanded by adding more countries to the existing analysis. The list of cultural regions where future cross-cultural automotive HMI research could be conducted is vast and any addition would certainly enhance the understanding of cross-cultural HMI design.
- This study did not include evaluation of task performance. Researchers seeking to conduct similar studies may wish to make use of task performance data comparisons (e.g., error rate, task completion time) in order to clarify the nature of differences that may exist between groups.
- Finally, this study only utilized and validated Hofstede's national dimensions for understanding regional automotive users' values. Other cultural models are available to HCI practitioners such as, Trompenaars onion model (1994) and Hall's cultural factors (1959). These models should be explored for future automotive HMI design utilization. The validity and applicability of other models may provide a clarification for automotive HMI designers as to which model is appropriate in automotive industries and provide further insight into the cultural influence of regional users' preferences.

This study also raises the possibility of further research in the following areas:

- A difficulty experienced in this research was establishing a clear relationship between regional users' cultural background and their HMI design preferences. Therefore, further research is needed on the conceptualization and operationalization of regional automotive user behavior as well as on the relationship between perceived usability, cultural influence, and design preferences. This should include exploration of the relationship between performance and preference, and the extent to which these drive purchase decisions.
- The results of the VSM analysis completed in this research produced inconsistent outcomes compared to the cultural theories. In interpreting these results it is recommended that automotive designers should examine the VSM with various types of participants of different ages and professions to check the consistency of the outcomes to allay any concerns relating to the reliability of the model.

Conclusion

This paper demonstrates how designers can apply existing cross-cultural theories and methodologies from HCI to the investigation of cultural differences in order to understand users' requirements for automotive HMI design. The findings suggest that cultural differences may exist and can be documented in the area of HMI design and user needs analysis. From the results much valuable information can be summarized: what most UK drivers may perceive as Indifferent requirements in automotive HMI features are viewed as Must-be or Attractive by Indian drivers in this study. The opposite is also true, whereby an HMI feature considered

Attractive by Indian drivers in this study is viewed as Reverse[1] by UK drivers. Thus the outcome of the study implies that automotive designers should consider regional differences when creating HMI solutions. It is our hope that this information will provide vehicle manufacturers, suppliers, and academics with a much-needed understanding of how automotive HMI solutions can be improved (and possibly custom configured) to appeal to a very wide range of end users in different regions of the world. In so doing, this study provides a foundation to be used in further research into accommodating cultural influence in automotive HMI design.

Tips for Usability Practitioners

Automotive UI designers and usability practitioners should be aware of the following points:

- Keep in mind that some cultural dimensions are related to certain countries. For example, high Power Distance, Long-Term Orientation, and Collectivism significantly correlate with Indian culture. In comparison, Individualism and Short-Term Orientation correlate with UK culture.
- Generic cultural models such as Hofstede's cultural dimensions can make a measurable contribution to understand regional users' values when selecting automotive HMI design features. The dimensions can also allow designers to measure HMI system usability and user satisfaction towards system acceptability. However, automotive designers should exercise caution when using Hofstede VSM, as this research has shown that there are inconsistencies between derived theoretical dimensions and actual field study results.
- Although generalization of relationships between regional cultures and automotive users' design preferences and system acceptance need to be assessed further before a generic conclusion can be drawn, Marcus and Gould's guidelines may constitute a valid preliminary framework for capture of cross-cultural user requirements for automotive HMI designers.
- Incorporating cultural approaches and the study of local cultural preferences would be a powerful method in the design localization of future HMI. This is especially true, when the HMI system is developed in one region and the final assembled vehicle is sold in different regions with drivers having different cultural and technical background.
- Keep in mind that regional user preferences of automotive HMI design features may be culturally biased. Therefore the potential benefit of a culturally adapted HMI system should not be ignored and automotive manufacturers should encourage their designers and usability engineers to apply user centered design (UCD) approaches to incorporate cultural preferences from the target market.

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[1] Kano defined six-categories of requirements classification: Attractive (A), Must-be (M), One-dimensional (O), Indifferent (I), Reverse (R), and Questionable (Q; Kano et al., 1984; Berger et al. 1993). As per the CS formulae, this study primarily focused on investigating in the Kano model analysis for the One-dimensional, Must-be, Attractive, and Indifferent requirements.

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